
USDA
NRCS Natural Resources Conservation Service
Snow Survey and Water Supply Forecasting Program
Montana Data Collection Office
Snowmelt Peak Date Forecasting
Lucas Zukiewicz
Hydrologist

“You can compare one year to another in the mountains, but I can tell you from 30 years of experience, when it comes to snow there is no such thing as average.”

-Craig Skeie, City of Boulder Watershed Manager – when asked about if this is going to be an “average” runoff year by a young ecology graduate student working in an adjacent watershed

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Historical Timeline of Montana Snow Surveys

- 1922 – First recorded monthly snow course measurements taken in Montana at Mount Allen #7 and Iceberg Lake #3 in the St. Mary River Basin, now in Glacier National Park, as a joint venture between USGS and Water Survey of Canada.
- During August of 1935, snow courses were established in Wyoming and Yellowstone National Park.
- 1936 Corps of Engineers contributed $3,000 so that BAE could set up snow courses on the Columbia River basin.
- 1936 the district engineer of the US Geological Survey in Helena coordinated the snow survey measurements for the Missouri River.
- 1964 – First daily snow water equivalent measurements recorded at Lick Creek in the Hyalite Mountains south of Bozeman.

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Historical Timeline (continued)

- 1966- First daily reporting site brought on line (line-of-site transmission) in Montana at Shower Falls in the Hyalite Mountains south of Bozeman.
- May 5, 1972 – Maximum snow water equivalent measurement of 94.4″ at Bald Eagle Peak snow course, in the Cabinet Mountains. Snow depth was recorded at 176″.
- April 1977 – First SNOTEL radio installed at Lick Creek in the Hyalite Mountains south of Bozeman.
- The Bob Marshall snow survey takes about a week to complete and is about an 80 mile round trip each survey.

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2010 Snow Survey and SNOTEL Data Collection Network

CURRENT MONTANA DATA COLLECTION NETWORK

127 SNOTEL Sites (88 in Montana; 37 in Wyoming; 2 in Black Hills of South Dakota) report snow water equivalent, snow depth, precipitation, and temperature data eight times daily. During spring and early summer snow melt period, data collection can be increased to hourly reports to assist local Avalanche Centers, National Weather Service and Alberta Environment, Canada, during flood forecasting and climate monitoring activities.

8 SCAN Sites (Soil Climate Analysis Network) in Montana

170 Snow Courses (142 in Montana; 26 in Wyoming; 2 in Black Hills of South Dakota).

1 NEW SNOTEL site planned for 2010 in Montana
3 NEW SNOTEL sites planned for 2010 in Wyoming

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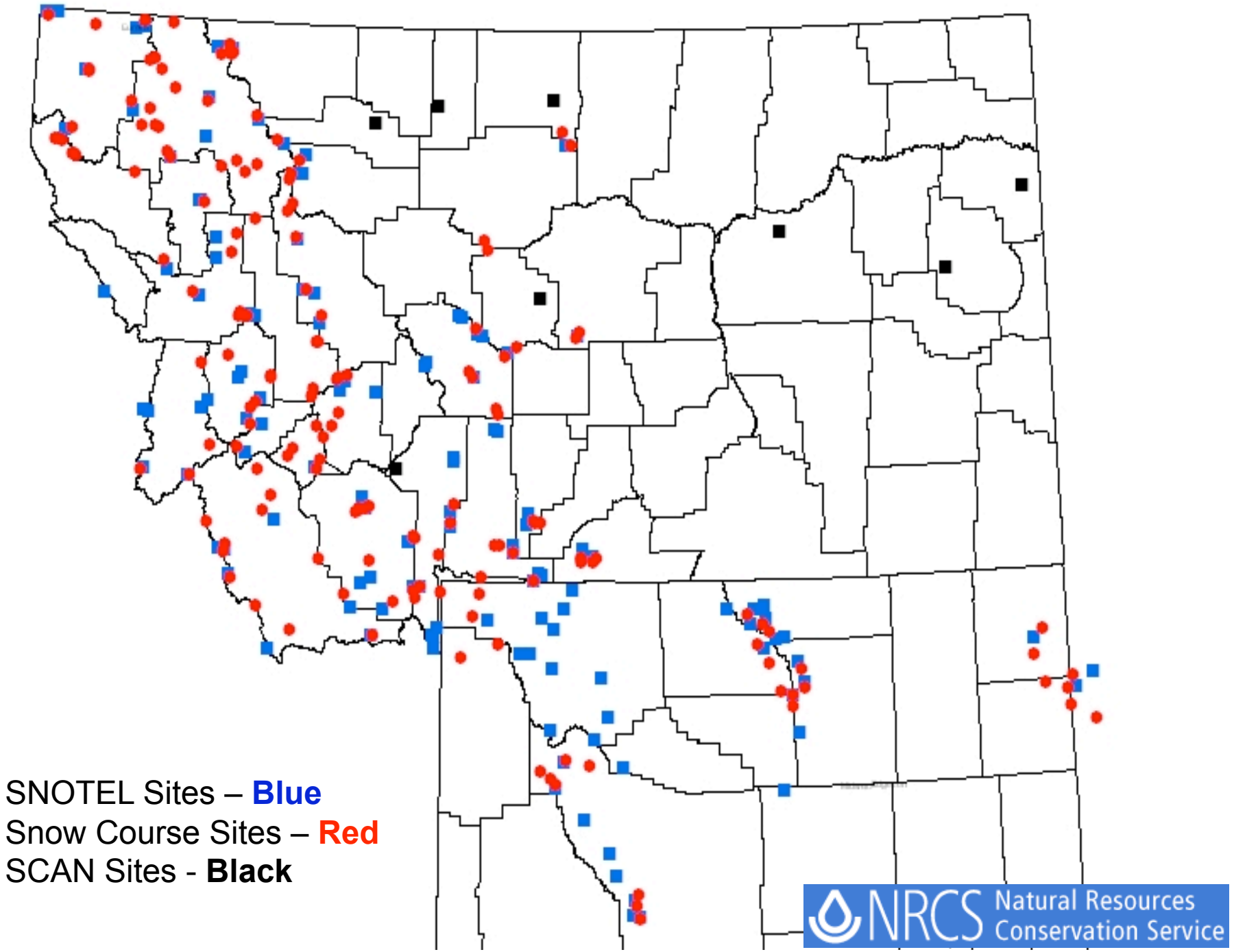
SNOTEL Sites – Blue
Snow Course Sites – Red
SCAN Sites - Black
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MEASURED PARAMETERS

ALL SITES

SNOW WATER EQUIVALENT (SWE) – Daily Value and Accumulated Through Water Year Snow Pillow and Manual Measurement (SNOTEL and SNOW COURSE)

SNOW DEPTH – Daily Value with Snow Depth Sensor and Manual Measurement (SNOTEL and SNOW COURSE)

PRECIPITATION – Daily Total and Accumulated Through Water Year (SNOTEL)

AIR TEMPERATURE – Daily Average, Maximum and Minimum (SNOTEL)

SELECT SITES or COOPERATOR REQUESTS

Relative Humidity, Soil Water Content, Wind Speed, Wind Direction, Solar Radiation.

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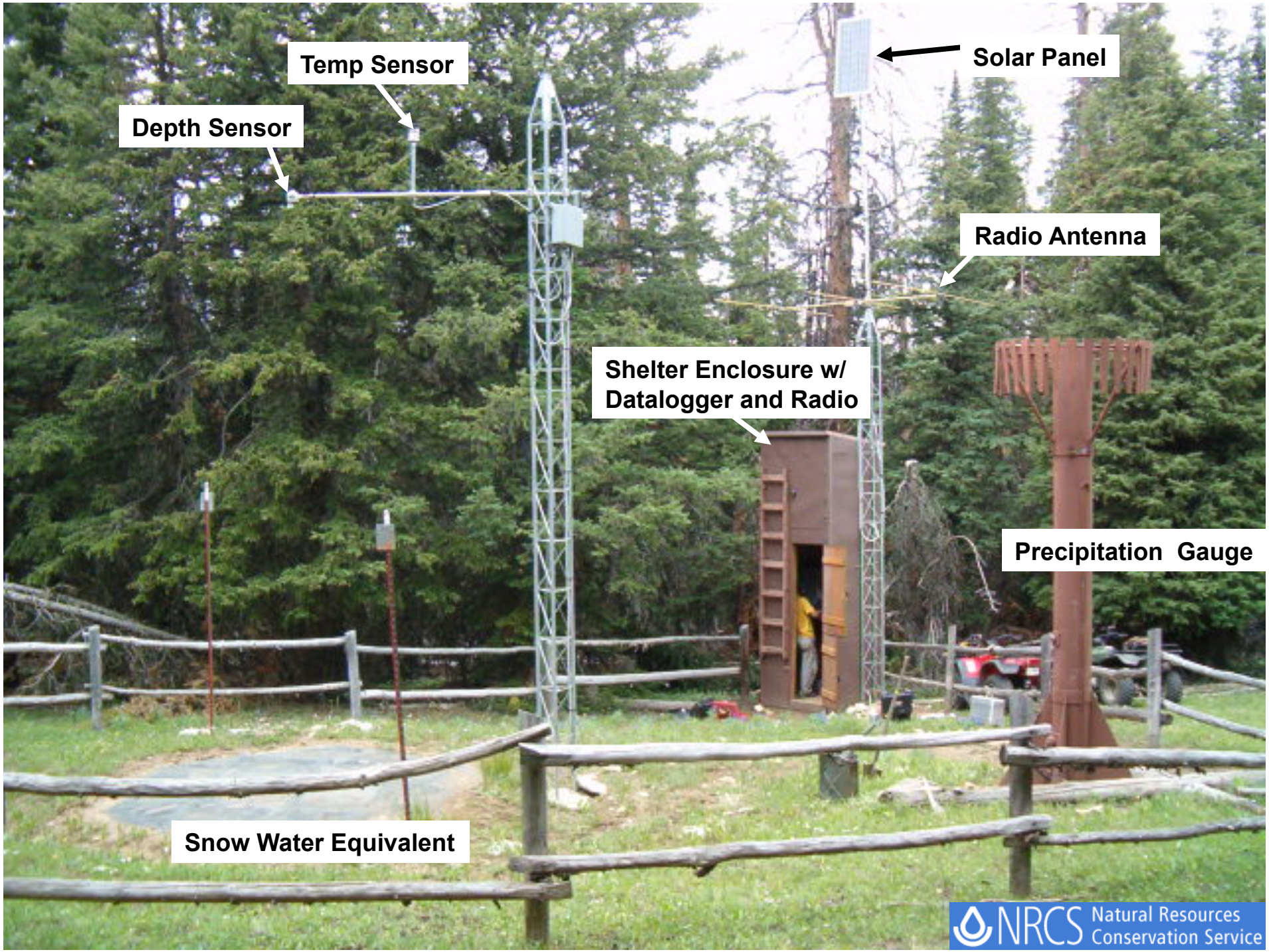
Temp Sensor
Depth Sensor
Solar Panel
Radio Antenna
Shelter Enclosure w/
Datalogger and Radio
Precipitation Gauge
Snow Water Equivalent
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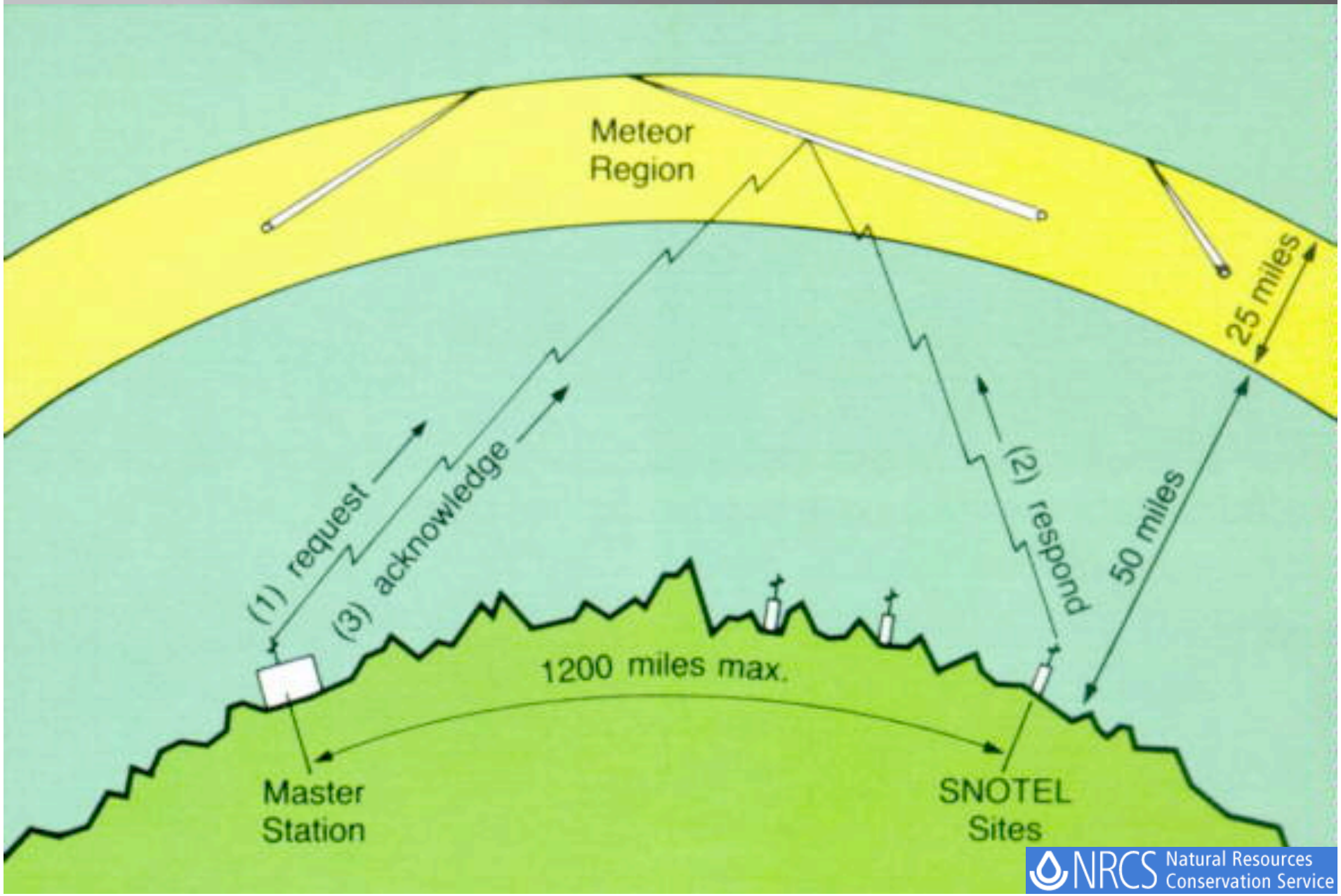
SNOTEL COMMUNICATION USING METEOR BURST TECHNOLOGY



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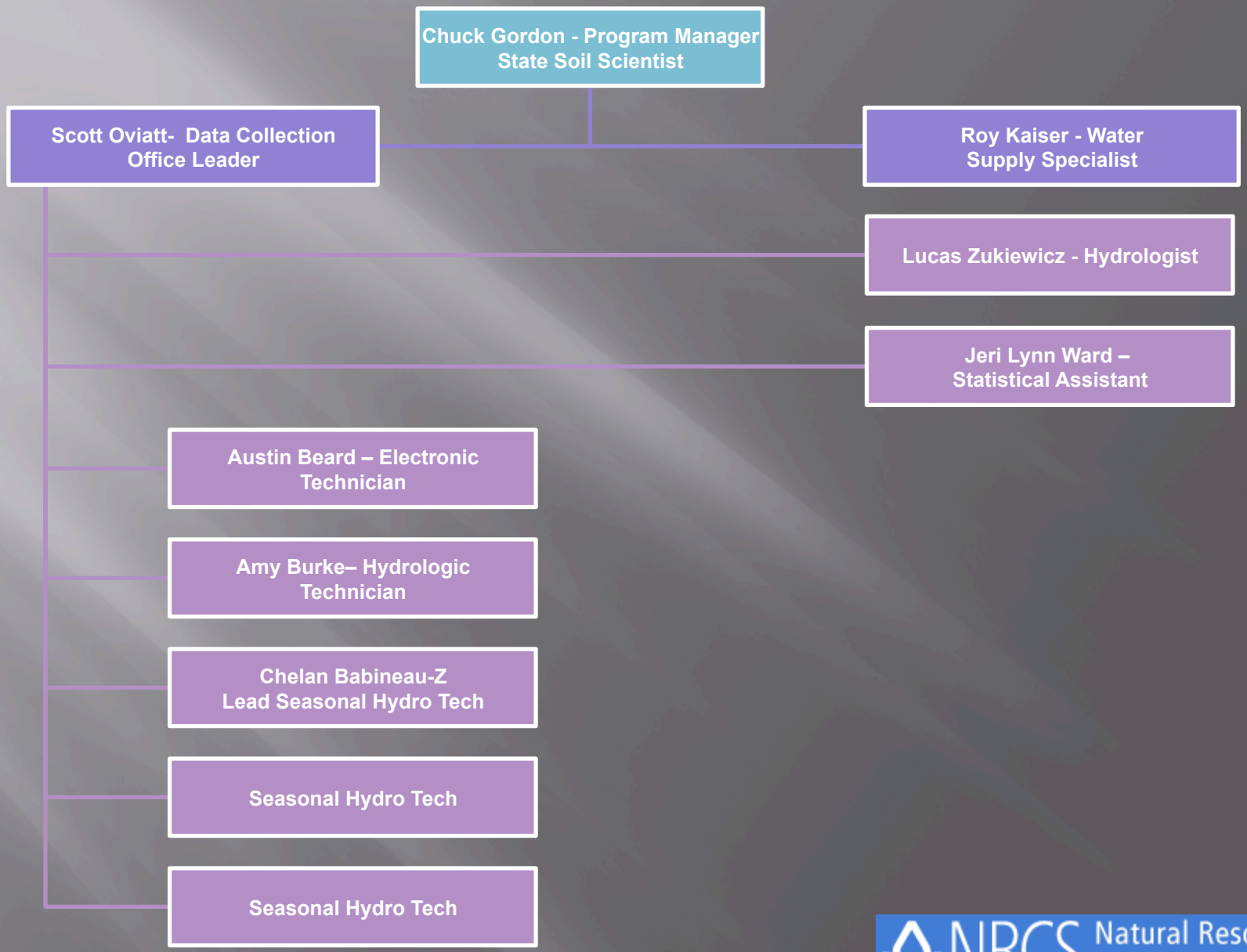
Montana Snow Survey Management Structure



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Data Collection and Analysis Duties

- Snow course data quality control and archival
- Snow course site maintenance
- SNOTEL data quality control, review and archival
- SNOTEL site maintenance
- SNOTEL site emergency repair and equipment removal (Fire)
- Snow data analysis, interpretation, for water supply determinations and forecasting
- Snow and water supply data dissemination to users and general public
- Develop and release state water supply outlook reports
- Handle media contacts and issue state news releases
- Works with state and other federal entities in assessing/mitigating flood and drought conditions

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Timeline of Forecasting Operations

- **Beginning of Water Year (October 1st)**
  - Assess soil moisture conditions going into winter
- **Winter (December-March)**
  - Monitor and measure snowpack conditions in the mountains via land, air surveys and SNOTEL
- **Spring (April-July)**
  - 2,060 seasonal volume water supply forecasts are issued at 98 stream gages to water managers and water users of Montana
  - 387 snowmelt peak forecasts are issued annually April through June. These forecast the date and volume of when streams and rivers should crest during the peak snowmelt periods. Snowmelt peak forecasts are used widely by Federal, State, and Local water users and water managers.
  - 154 low flow forecasts are issued for fish biologists, river floaters, irrigators, and local watershed groups so that they can plan in advance and mitigate the potential impacts of critically low streamflows
  - 520 Surface Water Supply Indexes (SWSI's) are produced for 52 individual watersheds in Montana January through October.

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SEASONAL VOLUME FORECASTS

2,060 seasonal volume water supply forecasts are issued at 98 stream gages, January through June, to water managers and water users of Montana.

BITTERROOT nr Darby APR-JUL Average = 460.0	90% Exceedance	87%
	70% Exceedance	99%
	50% Exceedance	107% (490.00)
	30% Exceedance	114%
	10% Exceedance	126%
BITTERROOT nr Darby APR-SEP Average = 515.0	90% Exceedance	89%
	70% Exceedance	99%
	50% Exceedance	106% (545.00)
	30% Exceedance	113%
	10% Exceedance	122%

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LOW FLOW FORECASTS

154 low flow forecasts are issued for fish biologists, river floaters, irrigators, and local watershed groups so that they can plan in advance and mitigate the potential impacts of critically low streamflows.

Blackfoot River at Bonner updated August 18, 2009

Assuming average precipitation the Blackfoot River should reach 700 cfs between August 25 and August 29.

Assuming below average precipitation, the Blackfoot River should reach 700 cfs between August 20 and August 25.

Assuming well below average precipitation, the Blackfoot River should reach 700 cfs between August 13 and August 20.

This year the river reached 700 cfs on August 17. Last year (2007) the river reached 700 cfs on July 23.

This year the river receded to 2,000 cfs on July 14. Last year the river receded to 2,000 cfs on June 21.

This year the river receded to 1500 cfs on July 19. Last year the river receded to 1500 cfs on June 28.

This year the river receded to 1000 cfs on July 30. Last year the river receded to 1000 cfs on July 8.

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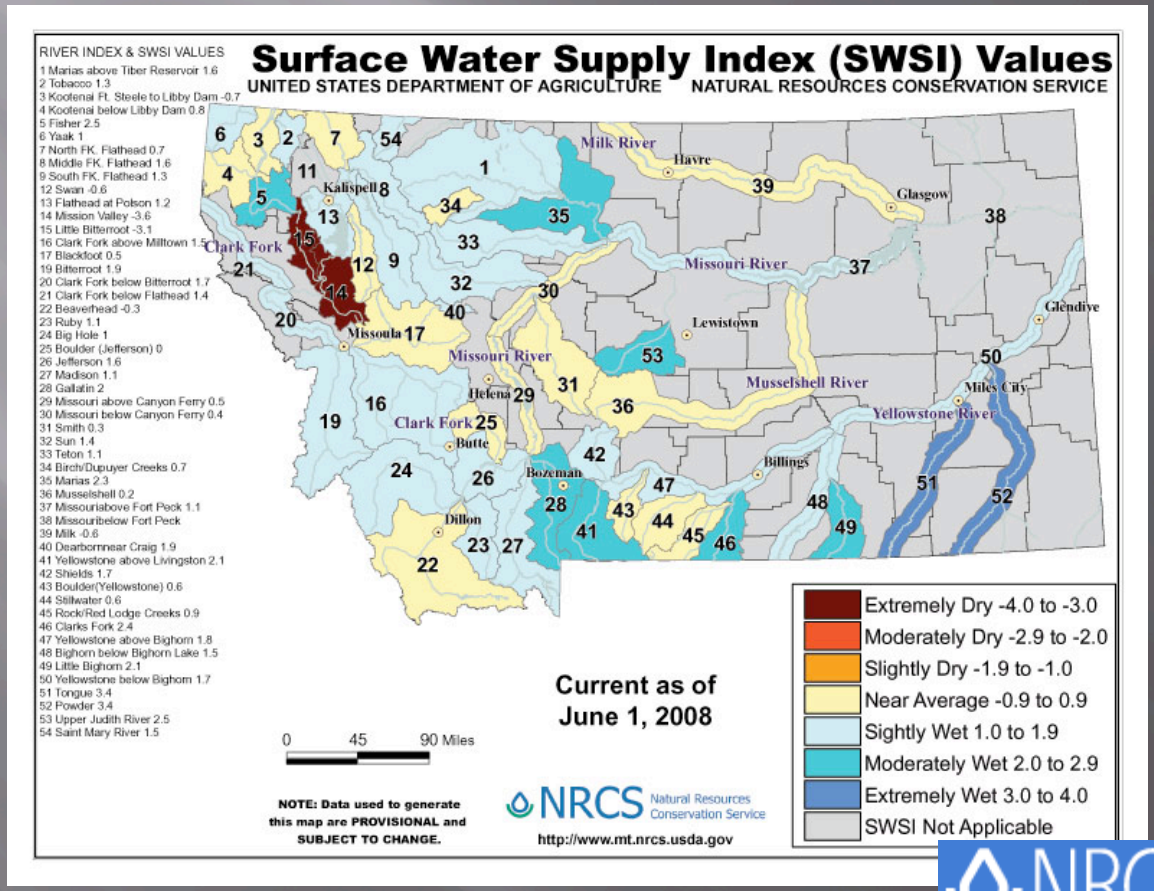
SURFACE WATER SUPPLY INDEX (SWSI)

520 Surface Water Supply Indexes (SWSI's) are produced for 52 individual watersheds in Montana January through October. SWSI's are utilized by the Governor's Drought Advisory Committee, USDA Farm Services Agency, and other state and federal agencies whose drought response is tied directly to SWSI values. During high runoff years, the Montana Disaster and Emergency Services utilizes SWSI's to help identify potential flood areas and mitigate possible flood damages. Montana SWSI's are also used by the National Drought Monitor authors to help determine drought designations in Montana.



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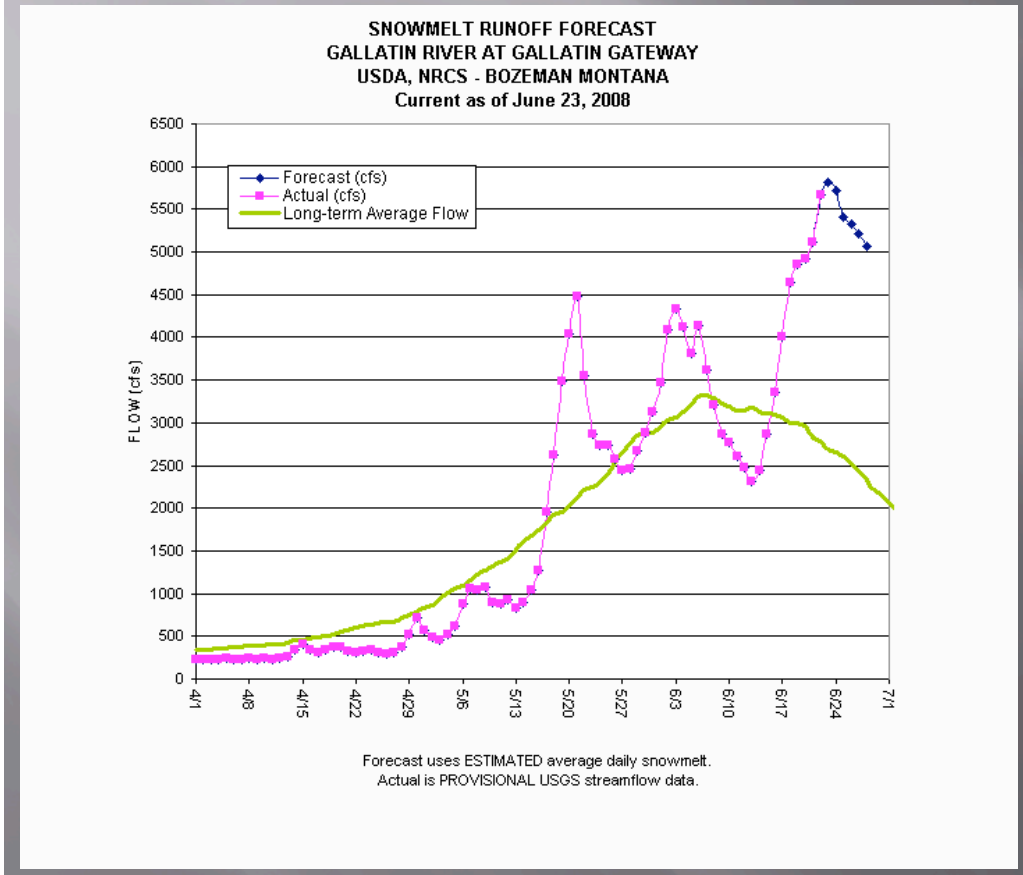
SNOWMELT PEAK FORECASTS

387 snowmelt peak forecasts are issued annually April through June. These forecast the date and volume of when streams and rivers should crest during the peak snowmelt periods. Snowmelt peak forecasts are used widely by Federal, State, and Local water users and water managers.



Snowmelt Peak Streamflow Forecasts based on May 1 data.

WATERSHED	PEAK FLOW DATES
COLUMBIA RIVER BASIN	
Bitterroot River near Darby	May 26 to June 8
Blackfoot River near Bonner	May 24 to May 31
Clark Fork River above Missoula	May 27 to June 8
Clark Fork River at St. Regis	May 28 to June 5

Snowmelt peak volume forecasts are computed using May 1 streamflow forecasts.

	PEAK RANGE	% OF AVE	AVE
COLUMBIA RIVER			
Bitterroot near Darby	4,900 to 7,600	90 to 139	5,454
Blackfoot near Bonner	7,000 to 10,800	82 to 127	8,512
Clark Fork ab Missoula	13,000 to 19,500	88 to 133	14,698
Clark Fork blw Missoula	25,000 to 37,500	88 to 132	28,482

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So how do we come up with our Peak Date forecasts?

Micro Scale-

- Cold Content Calculations (field data intensive)
- Energy Balance Methods (instrument intensive)

Radiation-Melt Graph

$$Q_{melt} = Q_{net\ short\ wave} + Q_{net\ long\ wave} + Q_{advected\ sensible} + Q_{evap\ condense} + Q_{ground} + Q_{rain} - Q_{stored\ energy}$$

Macro Scale-

- NRCS Snow Survey Regression (>30 yrs record; r^2 0.86 usual)

Predicted Runoff = R= a + bB +fF + pP +sS

R = Predicted Runoff Volume
B = Base Flow
F = Fall Precipitation (Antecedent Moisture)
P = Spring Precipitation
S = Snow water equivalent (April 15)

- SMPA model - Long-Term Regressional Statistics using real-time data
- VIPER model (Statistical Model) – Peak Stream Volumes, Low Flow Volumes
- BLASÉ model (Operational Model) – Peak Snowmelt Date

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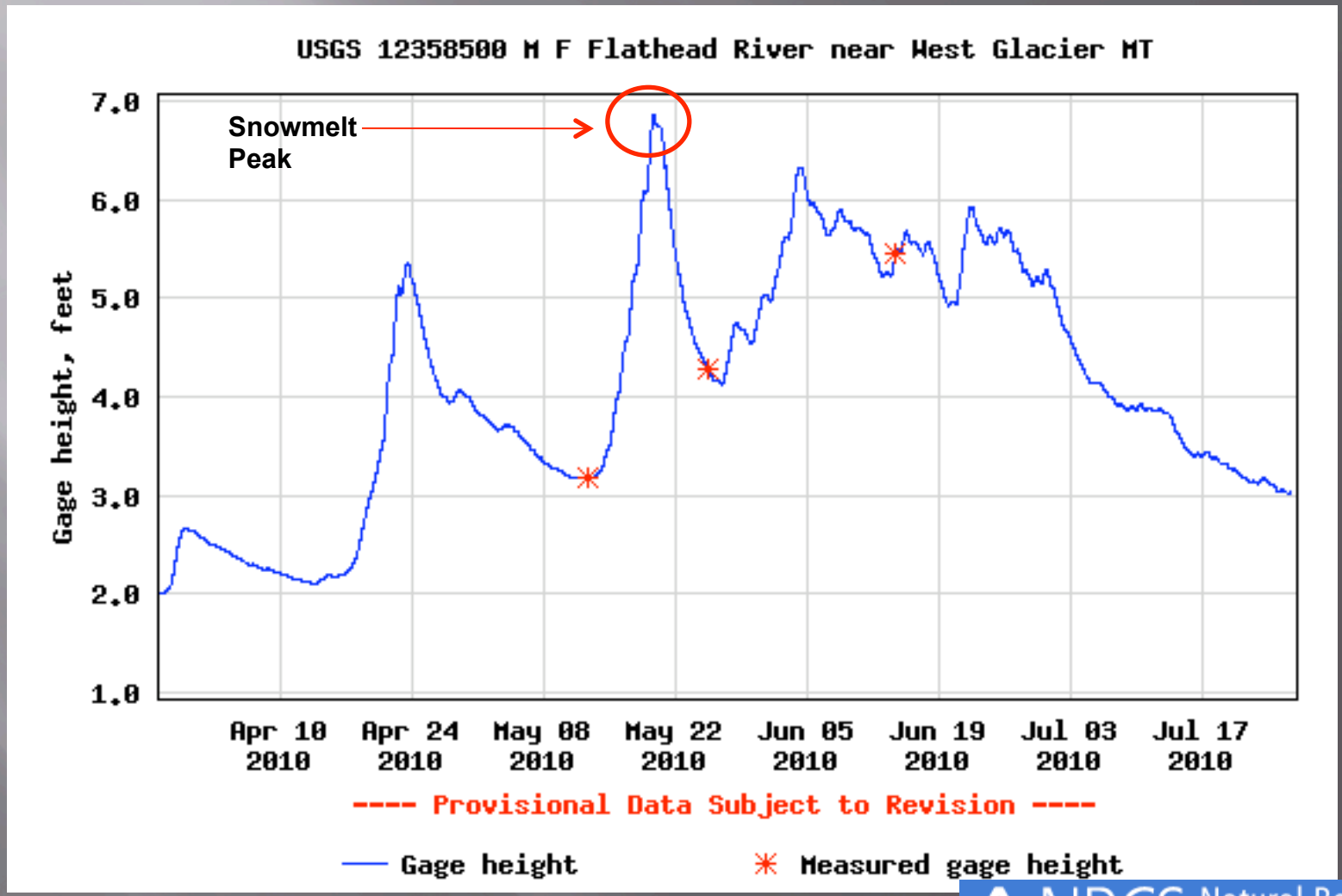
What exactly is the Snowmelt Peak Date?



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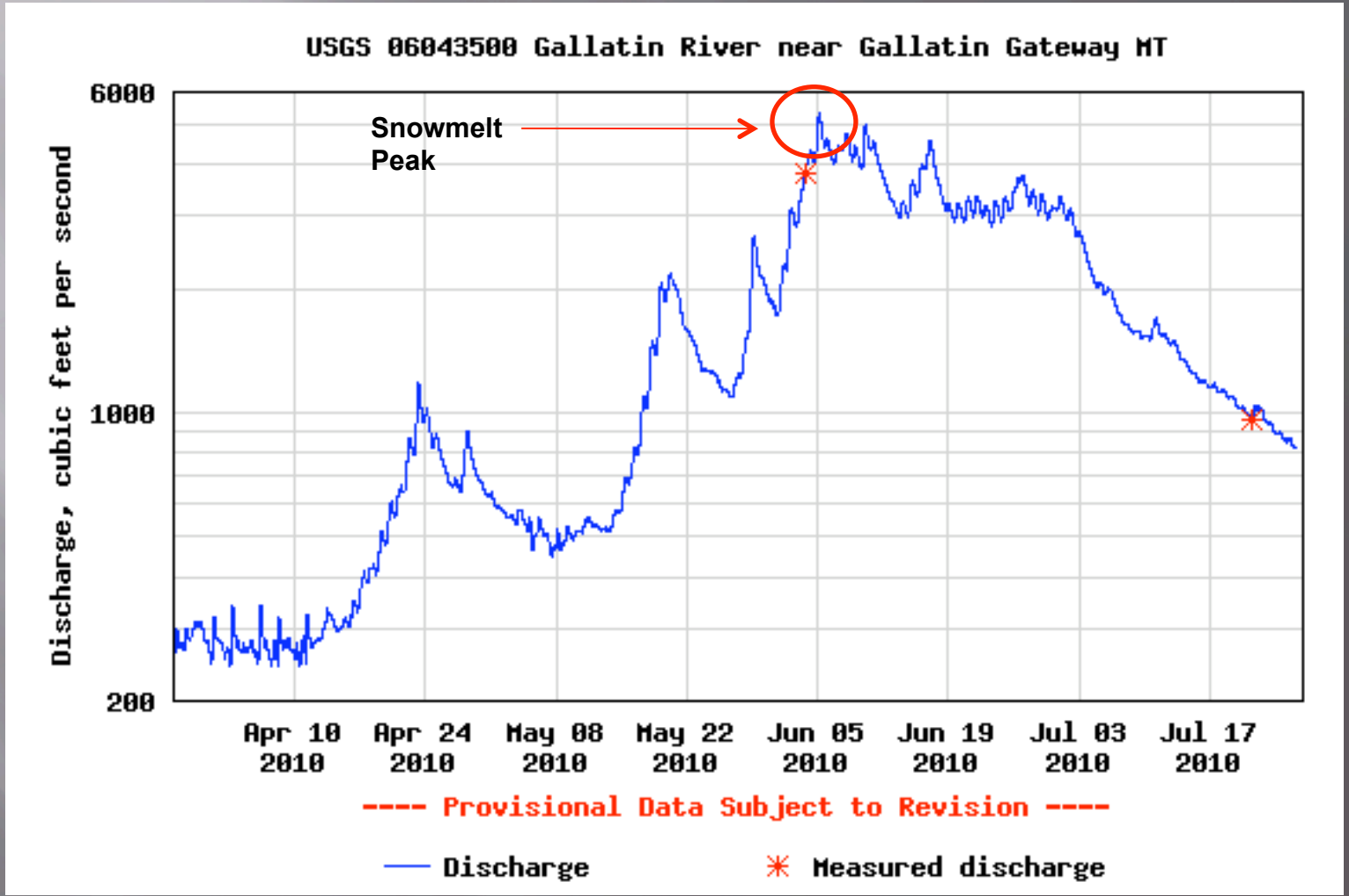
Sometimes it's straight forward



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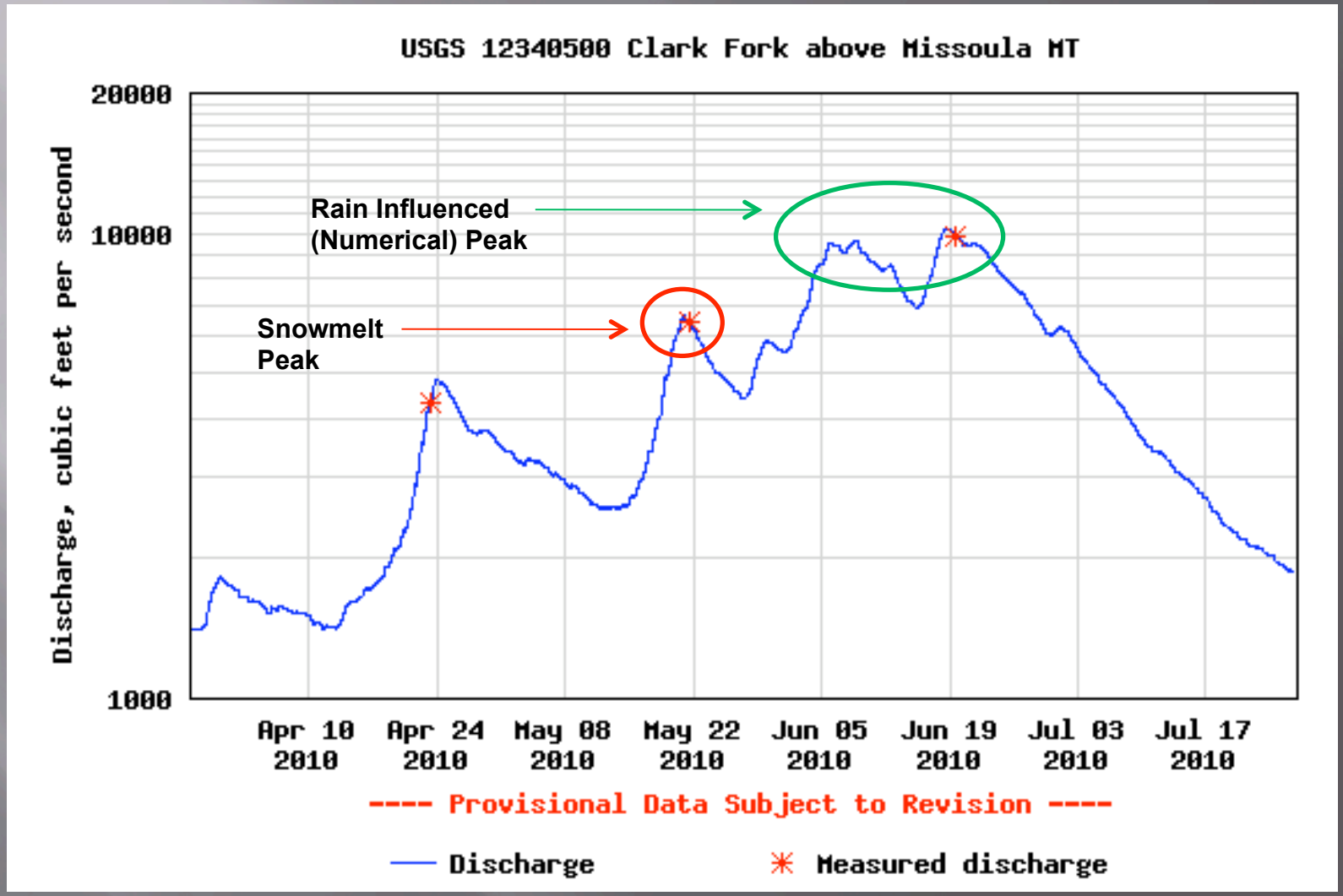
Sometimes it's not!



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Factors that make Peak Date Forecasting Difficult

- Soil Moisture Defecits entering Water Year
- Spatial limitation of data points
- Forecasting uncertainty in weather patterns
  - Cool/Wet vs Warm/Dry Springs
  - Differential Melting at Elevations in a Watershed early in Winter/Spring.
- Rain on Snow Events!!!

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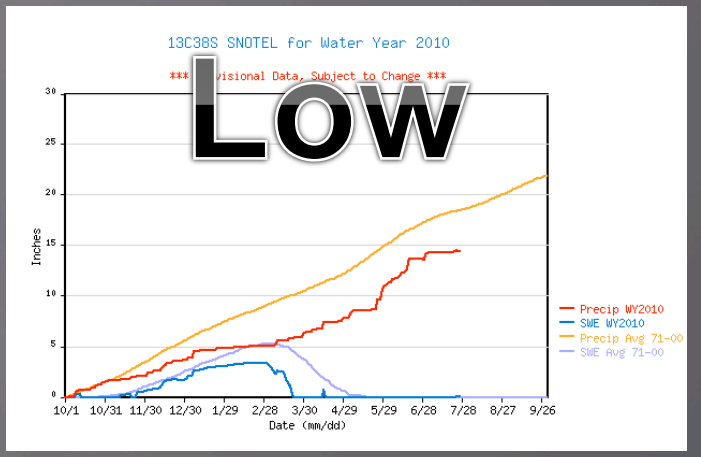
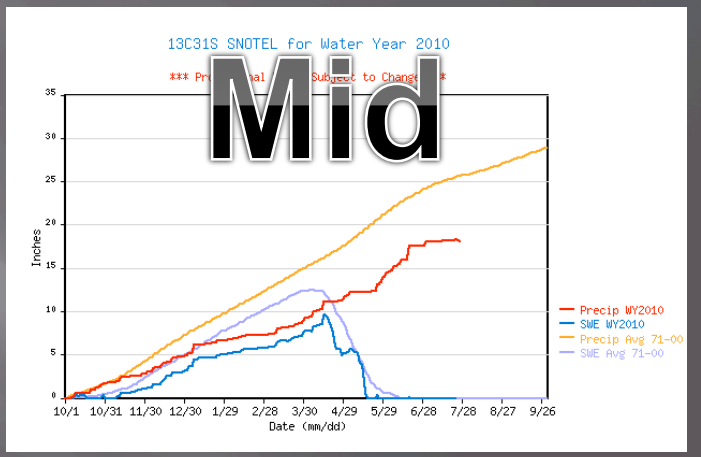
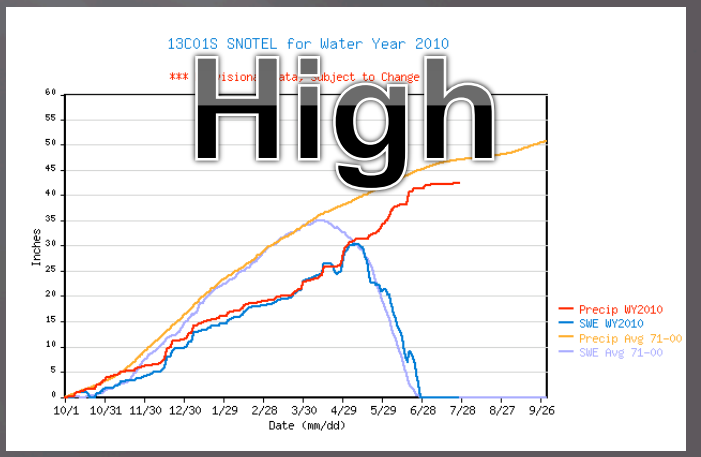
Verification of Peak Melt Dates

- Comparisons of SNOTEL sites by elevation in a watershed
- Anaylsis of Current Soil Moisture Conditions
- Daily Monitoring of the Hydrograph
- Model Runs





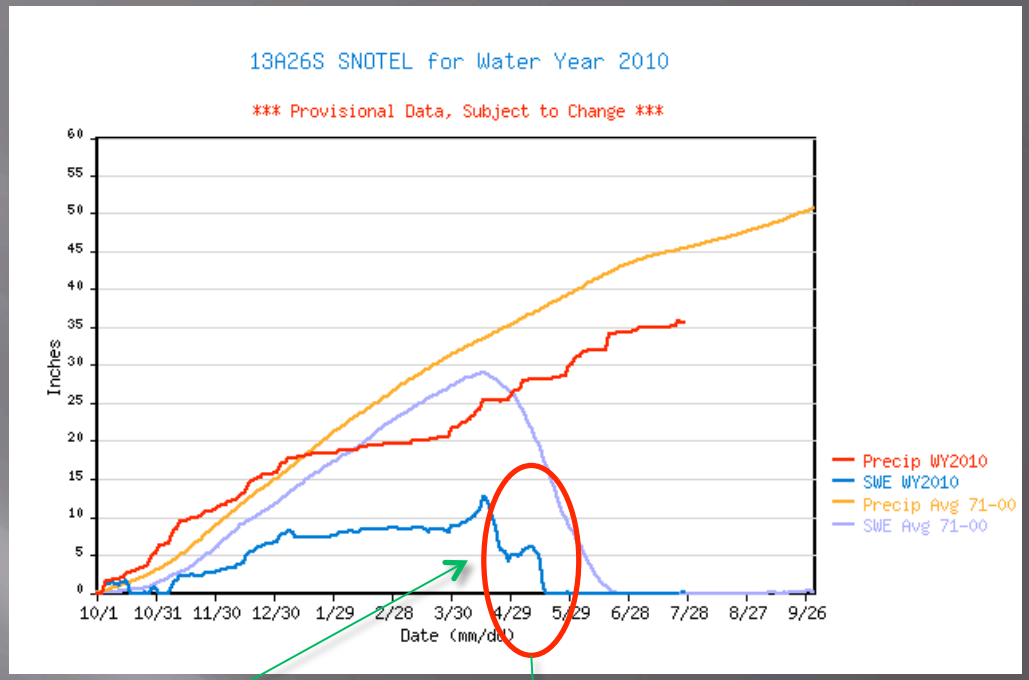


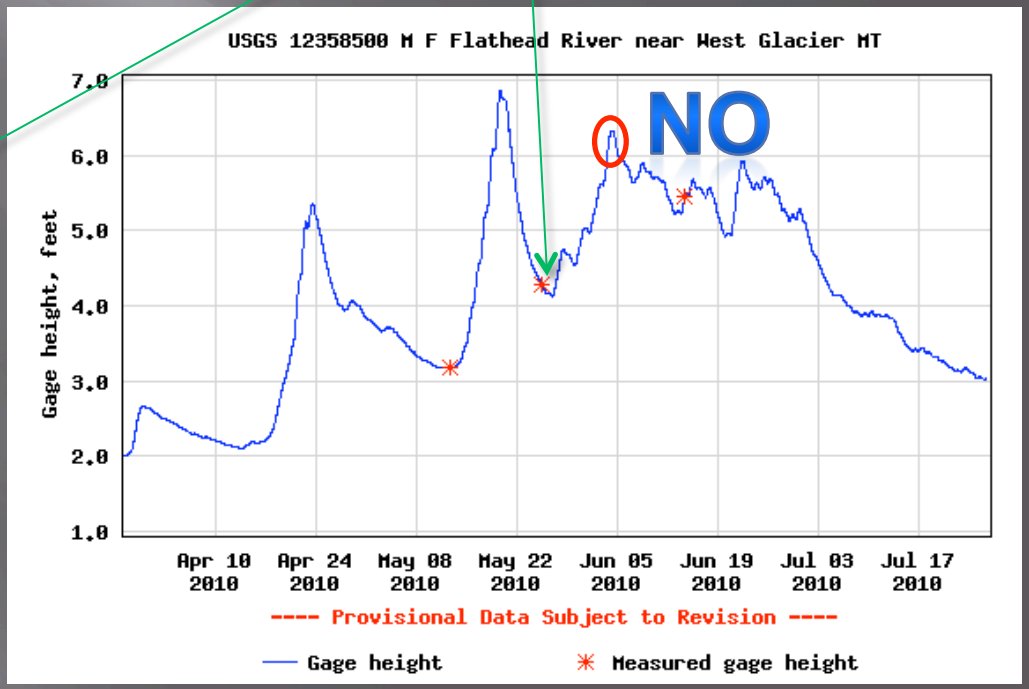
Verification of Peak Melt Dates

During years with multiple peaks in the Hydrograph

The Big Question is:

Is there enough available water at your major contributing elevations water for the flows to come back?

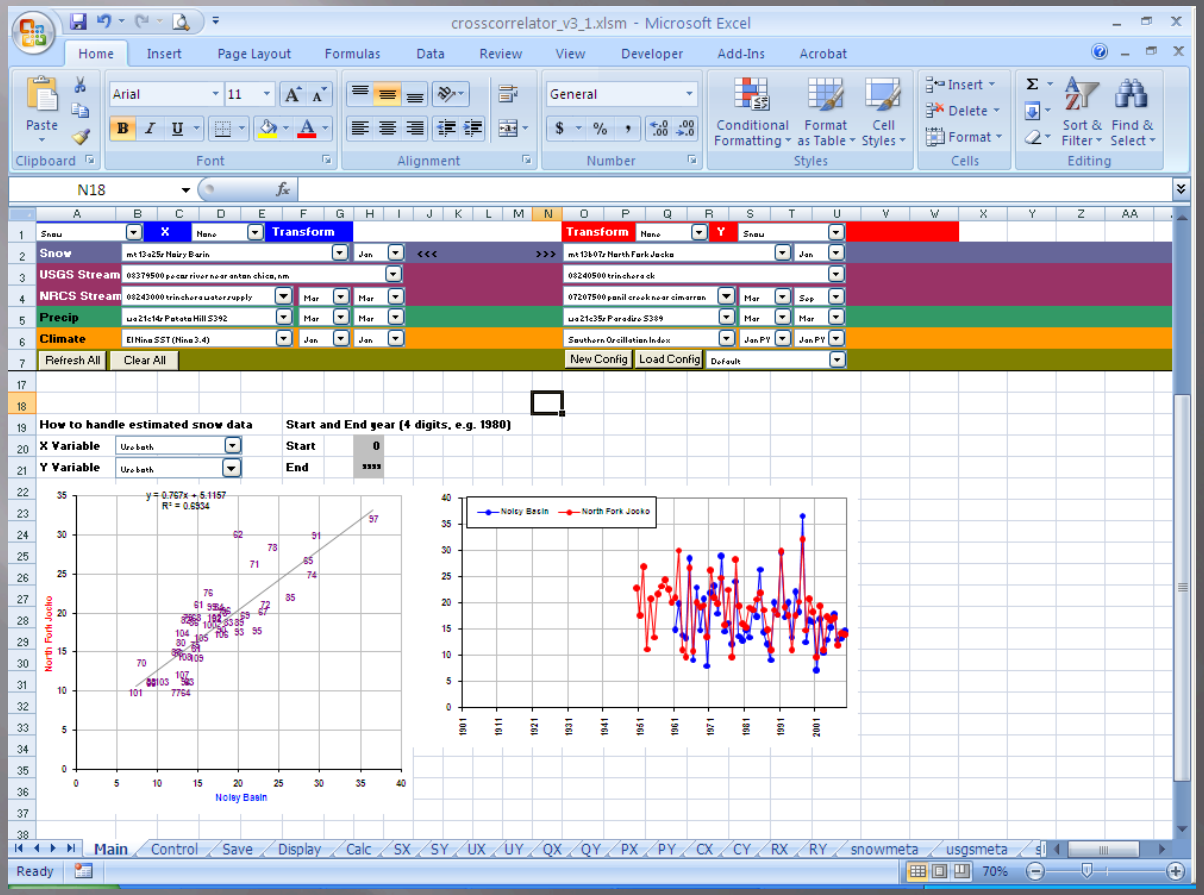




FORECASTING TOOLS

Regression/Correlation Tool

The regression tool can be used to compare multiple parameters from a Database to find the correlation between USGS gauged streams, SNOTEL sites, Snowcourses, and climate related data.



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SMPA

Gallatin River at Logan MT Peak Flow Date Forecasts

Return to Menu

			Todays is:	117	4/27
BEAVER CREEK	MAX SWE this year	14.2		Julian	Date
	CURRENT SWE	13.2	Early Peak	138	5/18
	Percent Melt	7%	Average Peak	155	6/4
	Melt Curve Used	10%	Late Peak	172	6/21
BRACKETT CREEK	MAX SWE this year	23.4		Julian	Date
	CURRENT SWE	17.8	Early Peak	137	5/17
	Percent Melt	24%	Average Peak	153	6/2
	Melt Curve Used	20%	Late Peak	169	6/18
CARROT BASIN	MAX SWE this year	22.0		Julian	Date
	CURRENT SWE	21.2	Early Peak	138	5/18
	Percent Melt	4%	Average Peak	155	6/4
	Melt Curve Used	0%	Late Peak	172	6/21
LICK CREEK	MAX SWE this year	10.9		Julian	Date
	CURRENT SWE	7.9	Early Peak	138	5/18
	Percent Melt	28%	Average Peak	156	6/5
	Melt Curve Used	30%	Late Peak	174	6/23

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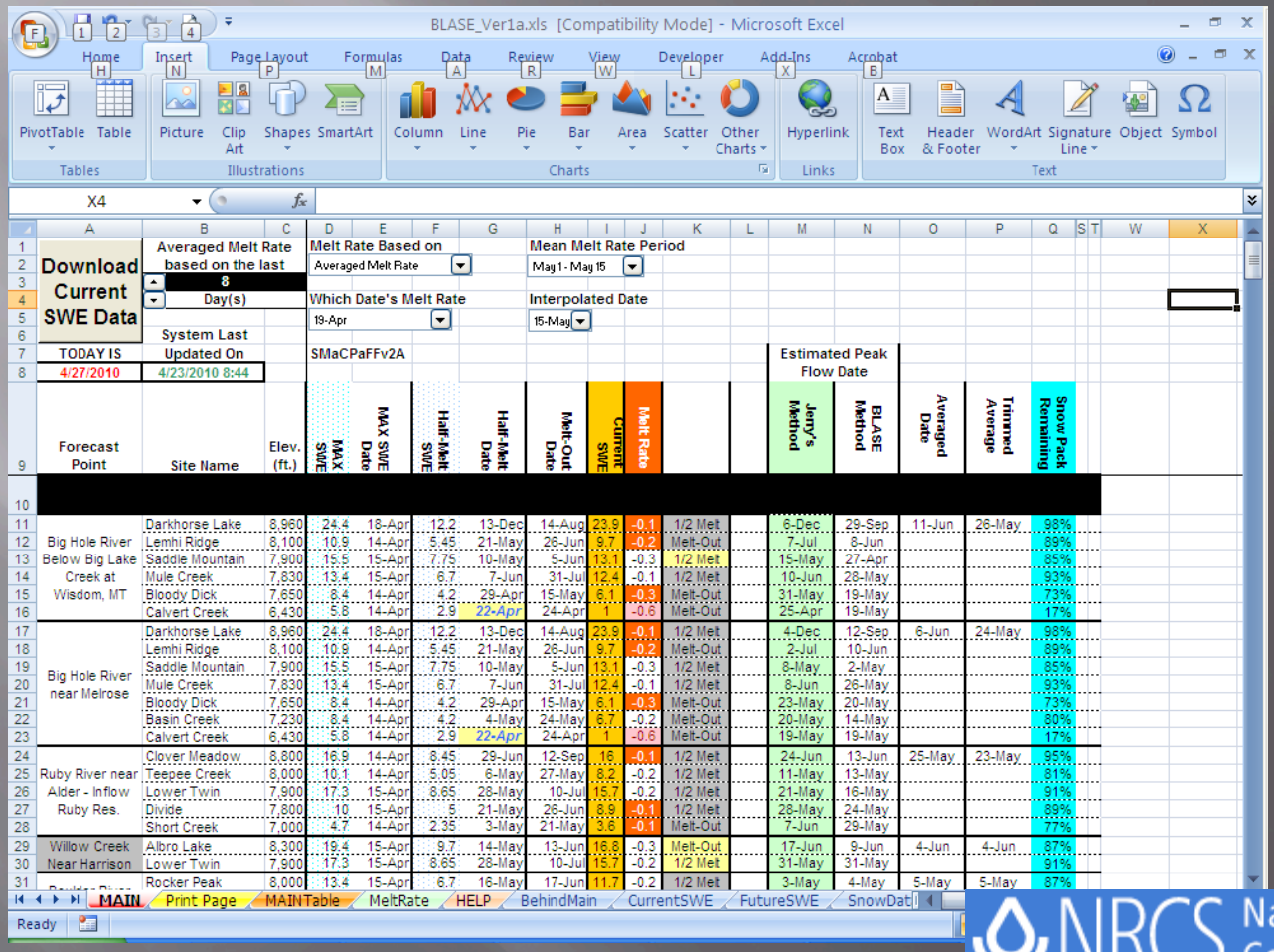
BLAZÉ Model

Operational Model based using real-time SNOTEL data. Allows user to project peak dates based on historical regression based statistics, and also enables multiple analytical techniques of real-time data of current melt to predict forward using data from a user defined period of time.



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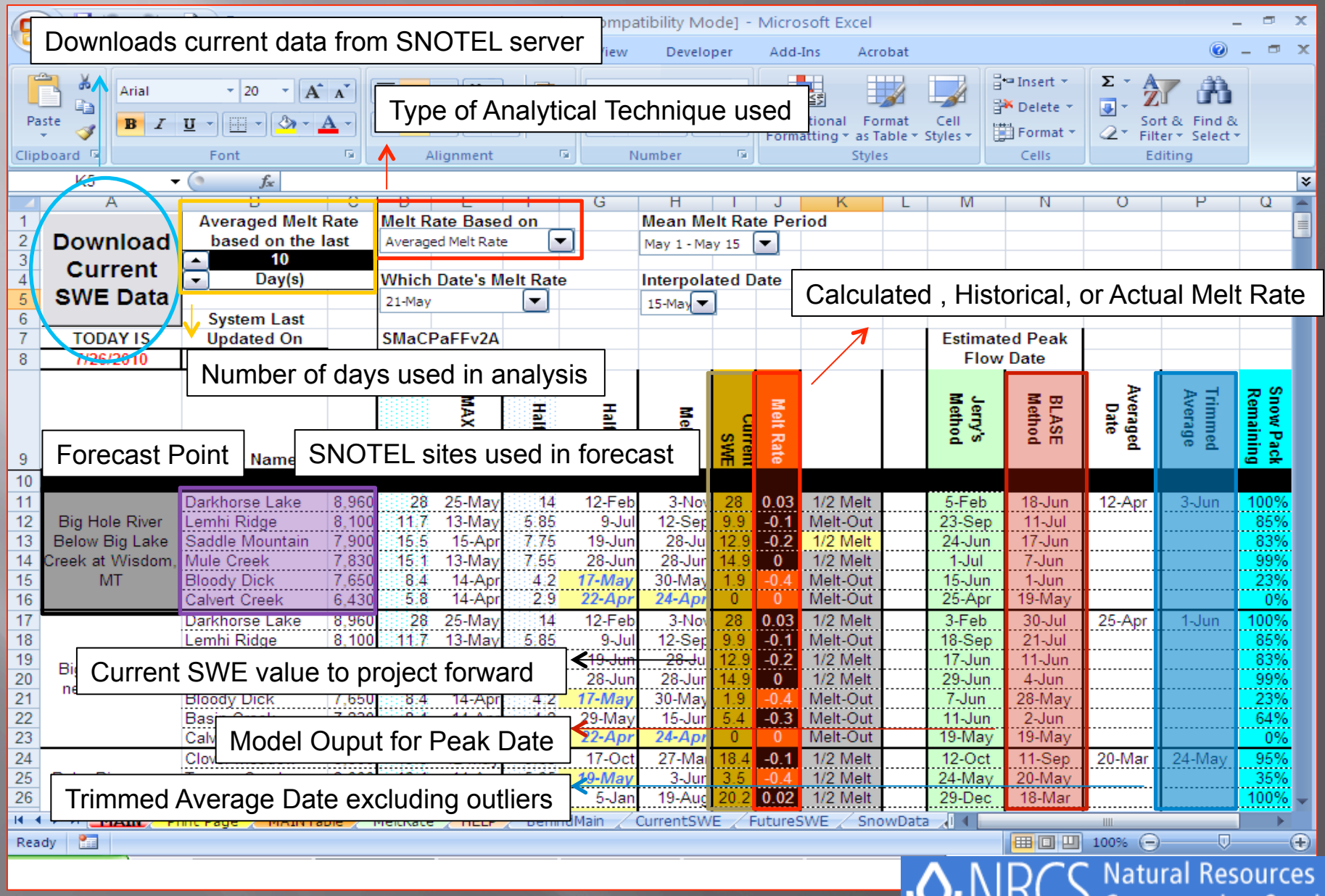
Blazé Model continued



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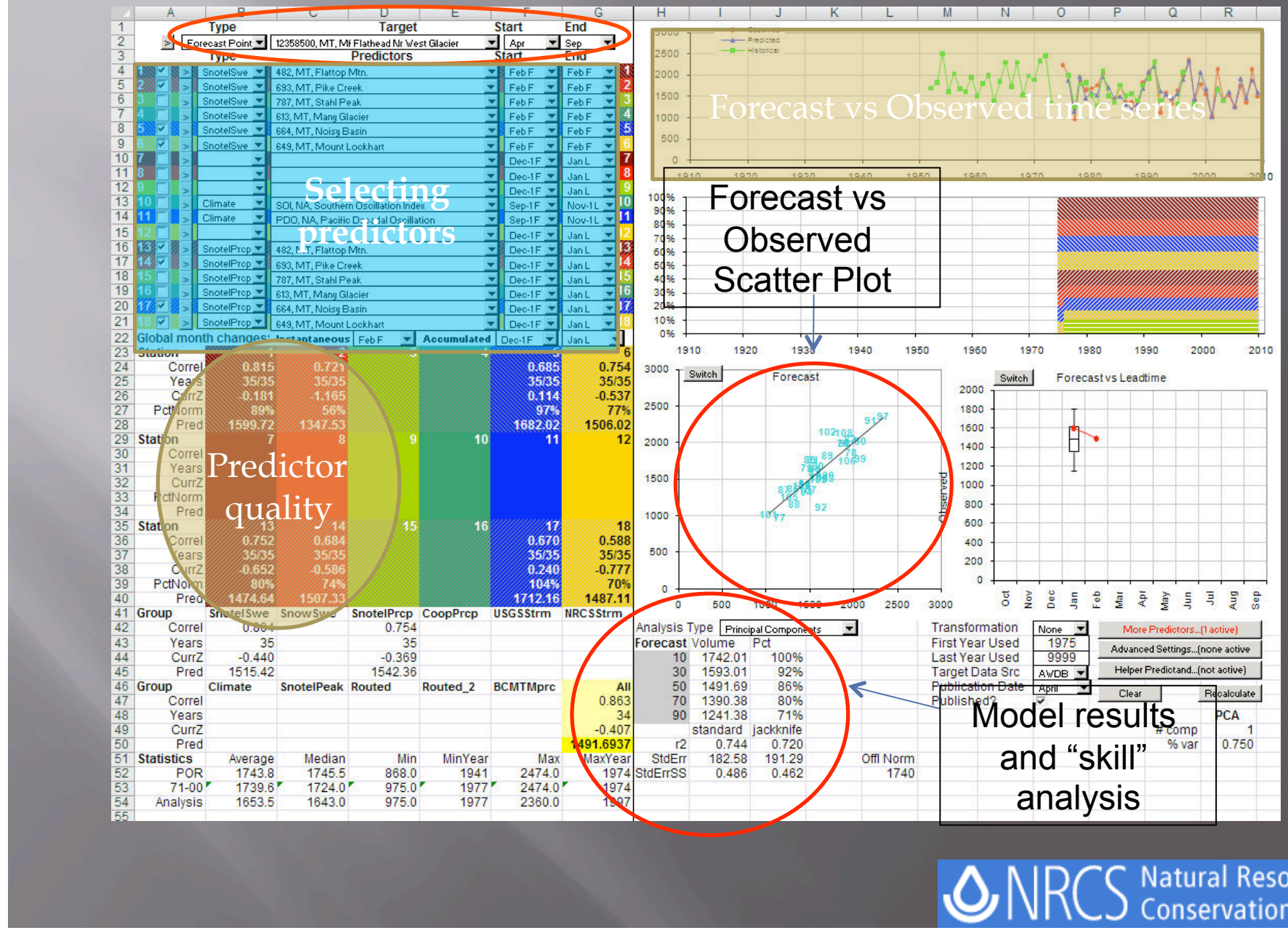
Blazé Model continued

- Still in development phase by the Montana DCO
- Shows promise for narrowing a date range for a forecast point over SMPA
- Integration of Historical data with real-time data allows user anticipation of weather and climate related variables in snow melt
- Will integrate predictor quality in future versions.

The Viper Platform



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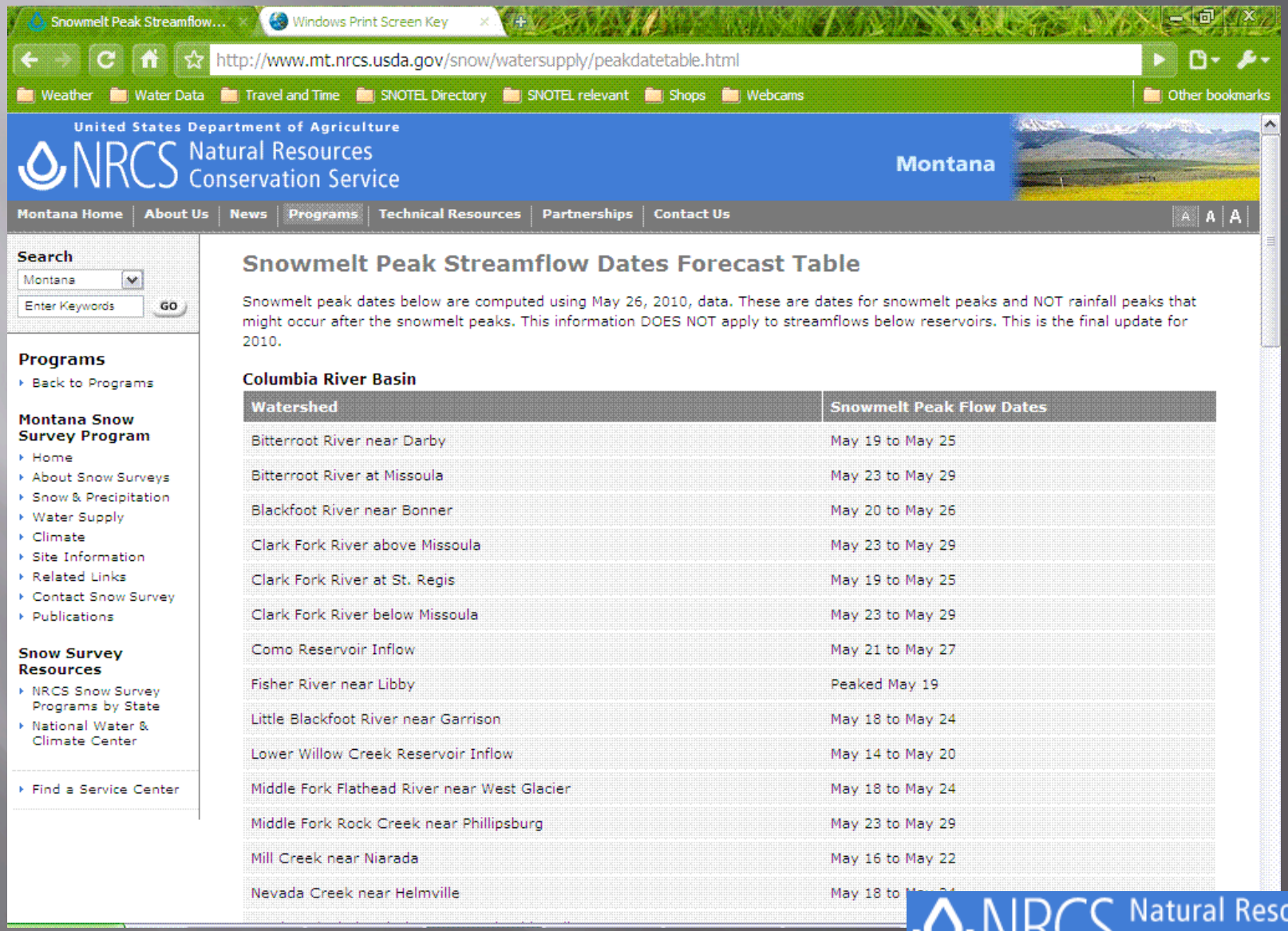
Peak Date Forecasts Online



SNOTEL PRODUCTS

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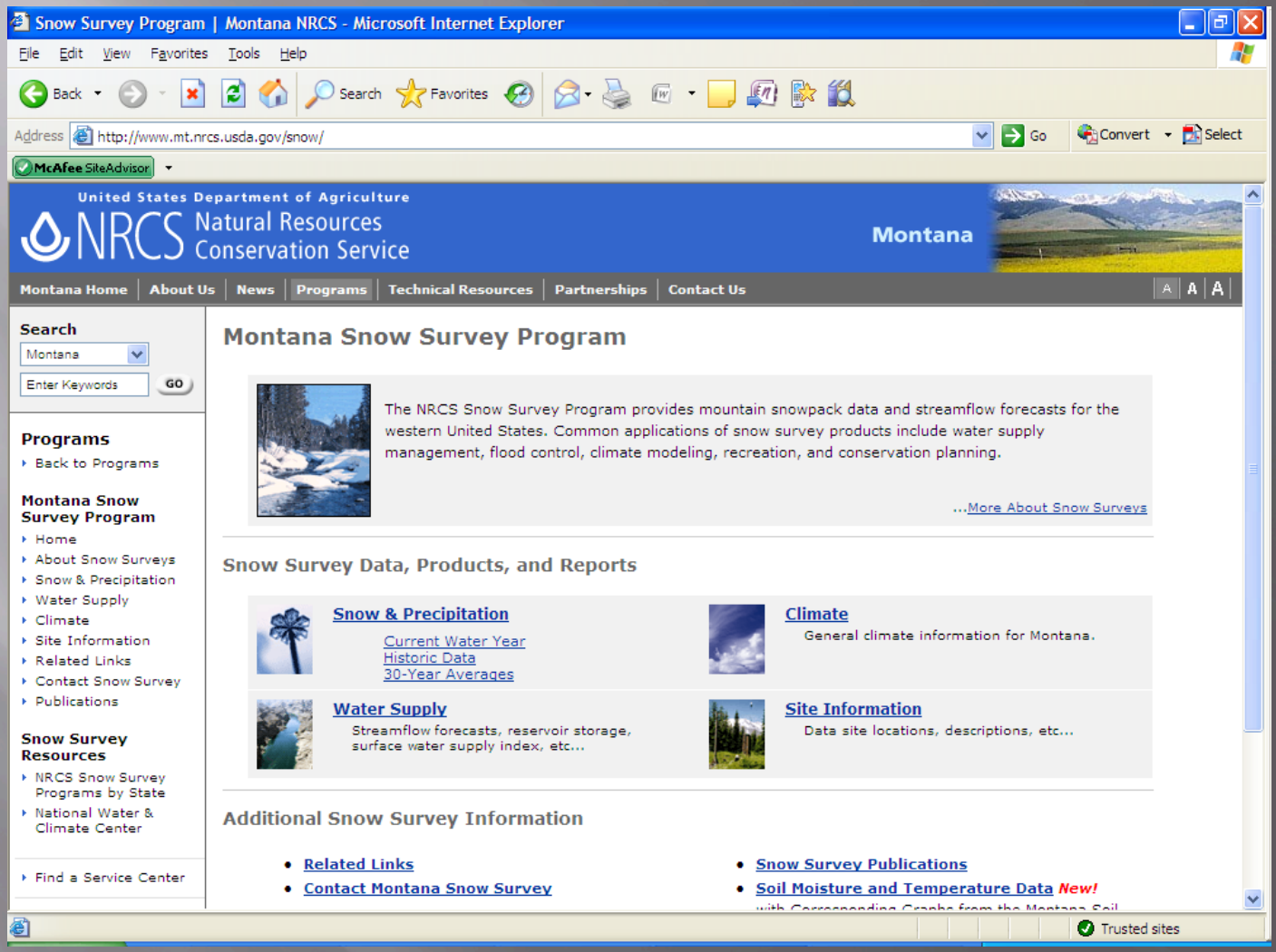
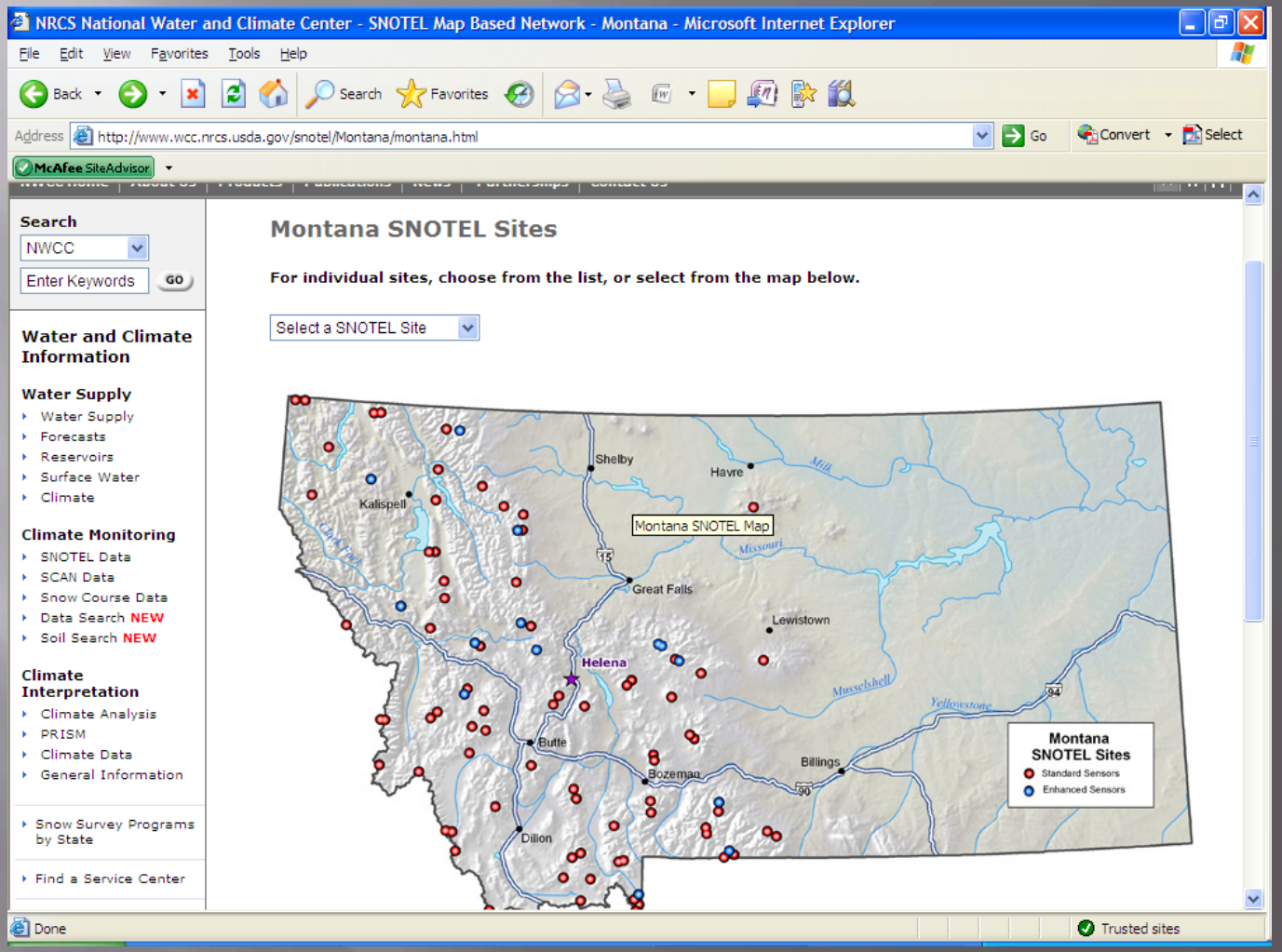
Web Based Services



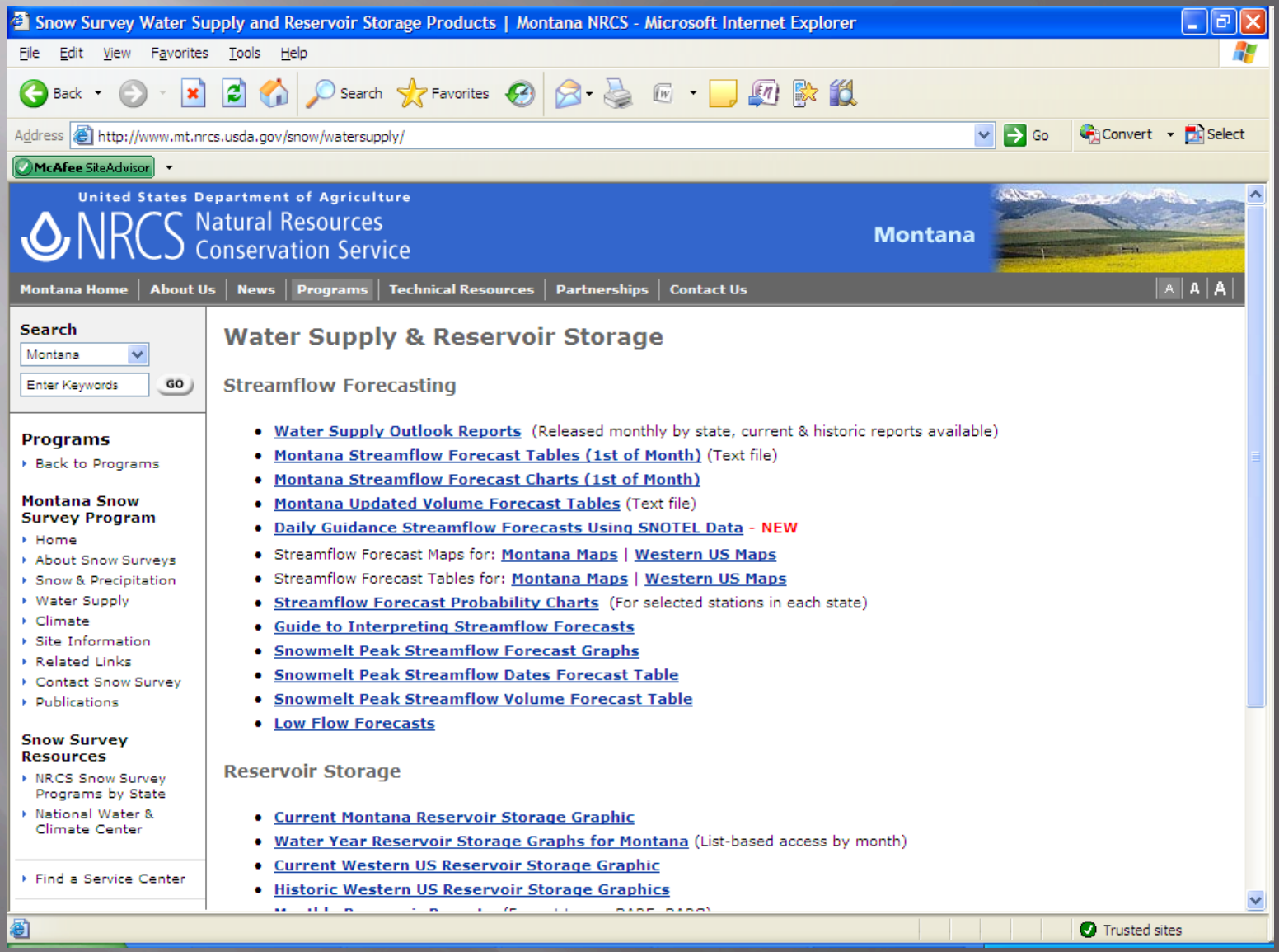
http://**www.mt.nrcs.usda.gov/snow/**

Web Based Services (cont.)

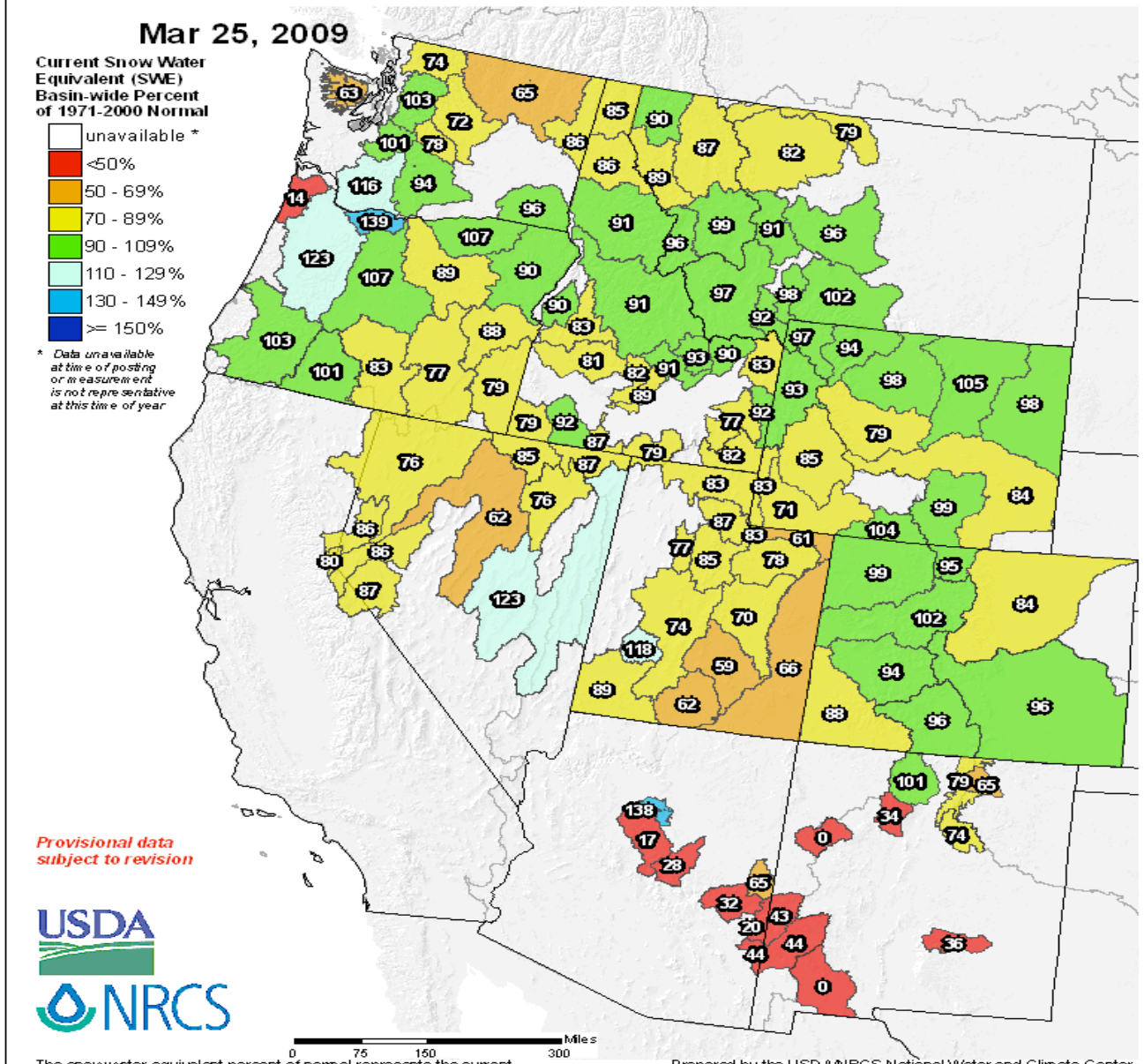


http://www.wcc.nrcs.usda.gov/snotel/Montana/montana.html

Web Based Services (cont.)



Westwide SNOTEL Current Snow Water Equivalent (SWE) % of Normal

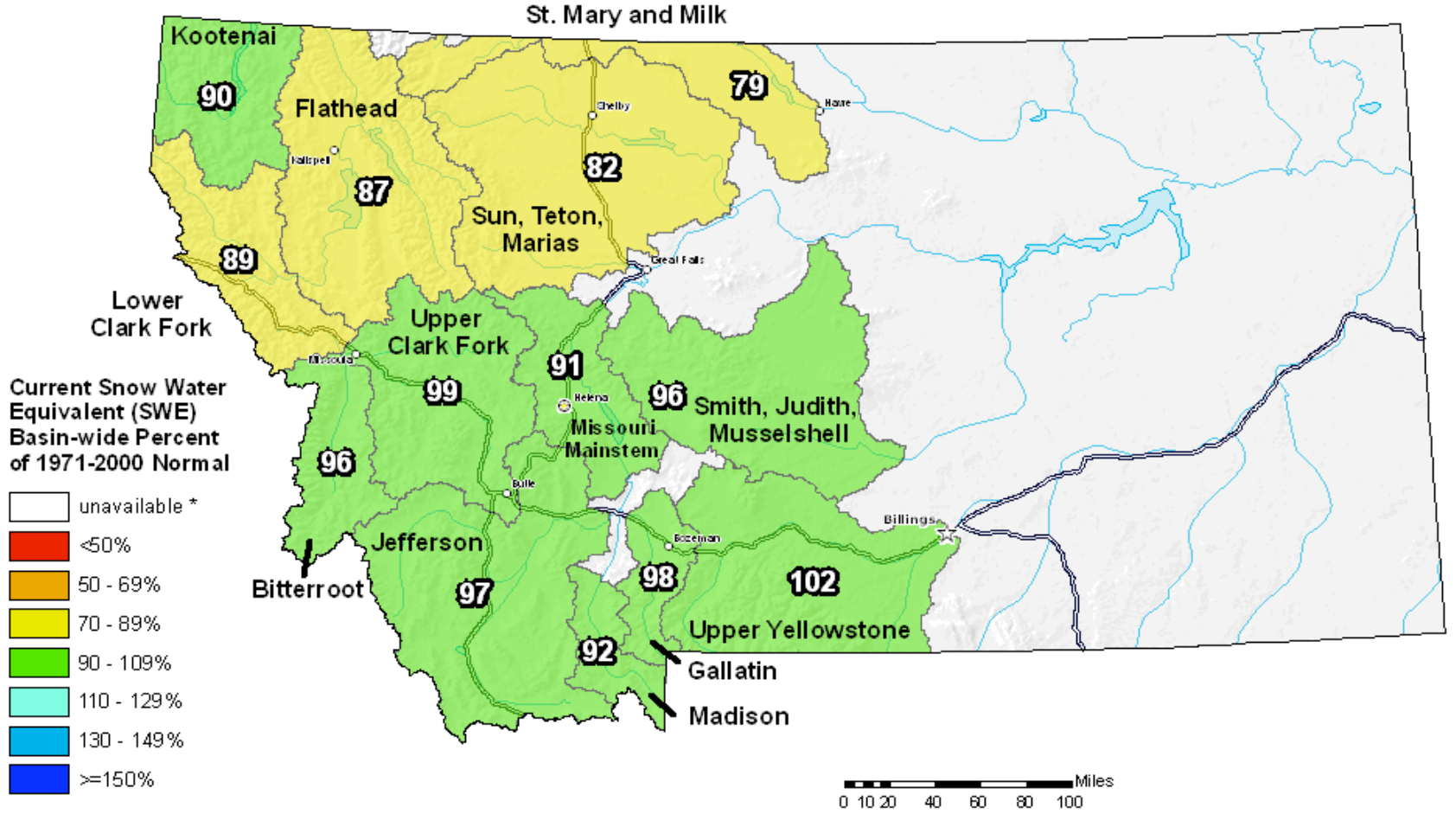


The snow water equivalent percent of normal represents the current snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).

Prepared by the USDA/NRCS National Water and Climate Center
Portland, Oregon http://www.wcc.nrcs.usda.gov/gis/
Based on data from http://www.wcc.nrcs.usda.gov/reports/
Science contact: Tom.Pagano@por.usda.gov 503 414 3010

Montana SNOTEL Current Snow Water Equivalent (SWE) % of Normal

Mar 25, 2009



Current Snow Water Equivalent (SWE) Basin-wide Percent of 1971-2000 Normal

- unavailable *
- <50%
- 50 - 69%
- 70 - 89%
- 90 - 109%
- 110 - 129%
- 130 - 149%
- >=150%

* *Data unavailable at time of posting or measurement is not representative at this time of year*

Provisional Data
Subject to Revision

The snow water equivalent percent of normal represents the current snowwater equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).

Prepared by the USDA/NRCS National Water and Climate Center
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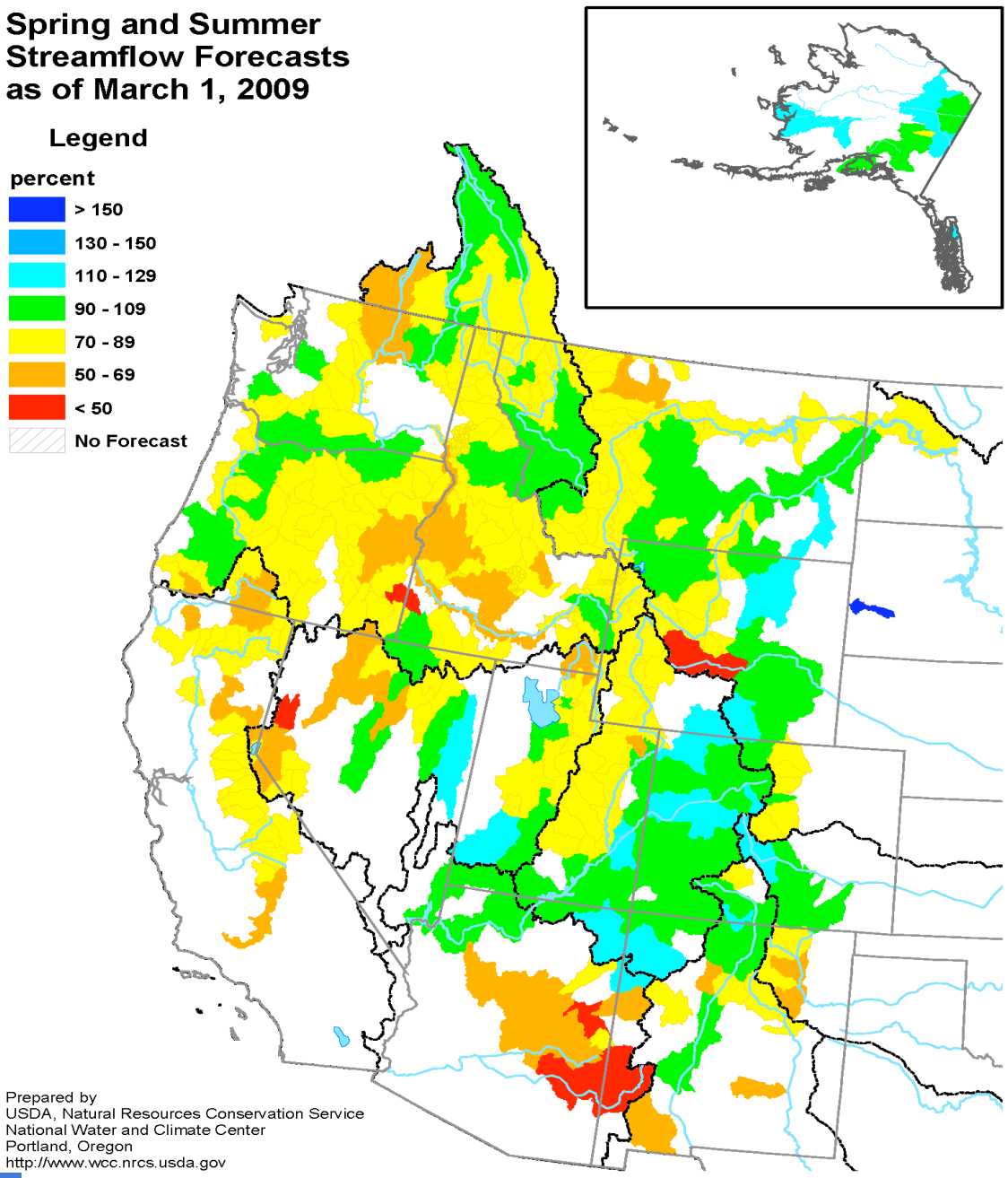
Spring and Summer Streamflow Forecasts as of March 1, 2009



Prepared by
USDA, Natural Resources Conservation Service
National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

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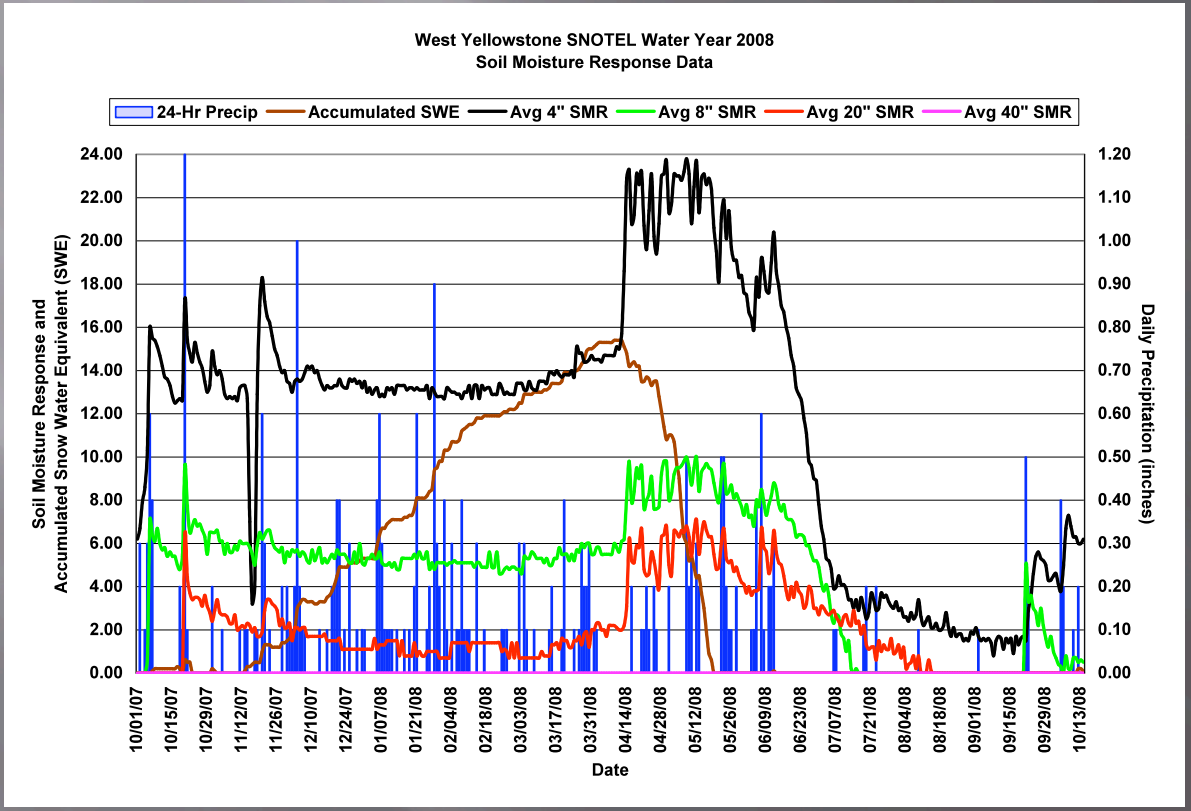
APPLYING NEW TECHNOLOGY TO SNOTEL SITES

Over the past three years, soil water content and soil temperature sensors have been added at select SNOTEL sites. This data will be incorporated into streamflow forecast models for antecedent and beginning of snowmelt soil moisture conditions.



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Future Direction for Runoff Forecasting

- Use of ArcGIS for basin analysis in selecting future SNOTEL sites
- Incorporate Remote Sensing technologies into an physically based model system. The existing SNOTEL system provides an excellent opportunity for long term records used in ground truthing aerial sensor outputs. This will provide real-time snow conditions for an entire basin, and move away from point-in-time measurements at fixed elevations and locations. This will allow us to monitor the entire water system.
- Incorporating emerging technologies at existing SNOTEL sites such as Fiber Optic Distributed Temperature Sensing (DTS), Ground Penetrating Radar (GPR) and Lydar, Fluidless Pillows, and Satellite Communications.

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Thanks for listening!